Fishery Data Series No. 06-40

Post-Hatchery Rearing of Juvenile Rainbow Trout in Fishless Ponds to Increase Survival to Age 1

by

April E. Behr

and

Cal Skaugstad

July 2006

Alaska Department of Fish and Game Divisions of Sport Fish and Commercial Fisheries

Symbols and Abbreviations

The following symbols and abbreviations, and others approved for the Système International d'Unités (SI), are used without definition in the following reports by the Divisions of Sport Fish and of Commercial Fisheries: Fishery Manuscripts, Fishery Data Series Reports, Fishery Management Reports, and Special Publications. All others, including deviations from definitions listed below, are noted in the text at first mention, as well as in the titles or footnotes of tables, and in figure or figure captions.

Weights and measures (metric)

centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
milliliter	mL
millimeter	mm

Weights and measures (English)

cubic feet per second	ft^3/s
foot	ft
gallon	gal
inch	in
mile	mi
nautical mile	nmi
ounce	oz
pound	lb
quart	qt
yard	yd

Time and temperature

day	d
degrees Celsius	°C
degrees Fahrenheit	°F
degrees kelvin	K
hour	h
minute	min
second	s

Physics and chemistry

all atomic symbols	
alternating current	AC
ampere	A
calorie	cal
direct current	DC
hertz	Hz
horsepower	hp
hydrogen ion activity (negative log of)	pH
parts per million	ppm
parts per thousand	ppt, ‰
volts	V
watts	W

General

Alaska Administrative Code	AAC
all commonly accepted abbreviations	e.g., Mr., Mrs., AM, PM, etc.
all commonly accepted professional titles	e.g., Dr., Ph.D., R.N., etc.
at	@
compass directions:	
east	E
north	N
south	S
west	W
copyright	©
corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
District of Columbia	D.C.
et alii (and others)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.
Federal Information Code	FIC
id est (that is)	i.e.
latitude or longitude	lat. or long.
monetary symbols (U.S.)	$, ¢
months (tables and figures): first three letters	Jan,...,Dec
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S.C.	United States Code
U.S. state	use two-letter abbreviations (e.g., AK, WA)

Measures (fisheries)

fork length	FL
mideye-to-fork	MEF
mideye-to-tail-fork	METF
standard length	SL
total length	TL

Mathematics, statistics

all standard mathematical signs, symbols and abbreviations	
alternate hypothesis	H_A
base of natural logarithm	*e*
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	(F, t, χ^2, etc.)
confidence interval	CI
correlation coefficient (multiple)	R
correlation coefficient (simple)	r
covariance	cov
degree (angular)	°
degrees of freedom	df
expected value	*E*
greater than	>
greater than or equal to	≥
harvest per unit effort	HPUE
less than	<
less than or equal to	≤
logarithm (natural)	ln
logarithm (base 10)	log
logarithm (specify base)	log_2, etc.
minute (angular)	'
not significant	NS
null hypothesis	H_O
percent	%
probability	P
probability of a type I error (rejection of the null hypothesis when true)	α
probability of a type II error (acceptance of the null hypothesis when false)	β
second (angular)	"
standard deviation	SD
standard error	SE
variance	
population	Var
sample	var

FISHERY DATA SERIES NO. 06-40

POST-HATCHERY REARING OF JUVENILE RAINBOW TROUT IN FISHLESS PONDS TO INCREASE SURVIVAL TO AGE 1

by

April E. Behr

and

Cal Skaugstad

Alaska Department of Fish and Game, Division of Sport Fish, Fairbanks

Alaska Department of Fish and Game
Division of Sport Fish, Research and Technical Services
333 Raspberry Road, Anchorage, Alaska, 99518-1565

July 2006

This investigation was partially financed by the Federal Aid in Sport Fish Restoration Act (16 U.S.C. 777-777K) under Project F-10-19, Job No. E-3-1

The Division of Sport Fish Fishery Data Series was established in 1987 for the publication of technically oriented results for a single project or group of closely related projects. Since 2004, the Division of Commercial Fisheries has also used the Fishery Data Series. Fishery Data Series reports are intended for fishery and other technical professionals. Fishery Data Series reports are available through the Alaska State Library and on the Internet: http://www.sf.adfg.state.ak.us/statewide/divreports/html/intersearch.cfm This publication has undergone editorial and peer review.

April Behr and Cal Skaugstad
Alaska Department of Fish and Game, Division of Sport Fish,
1300 College Road, Fairbanks, AK 99701-1599, USA

This document should be cited as:
Behr, A. E. and C. Skaugstad. 2006. Post-hatchery rearing of juvenile rainbow trout in fishless ponds to increase survival to age 1. Alaska Department of Fish and Game, Fishery Data Series No. 06-40, Anchorage.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

ABSTRACT

This study compared the relative survival rates to age 1 between two treatment groups of rainbow trout *Oncorhynchus mykiss*: Fry that were reared in ponds before stocking into Quartz Lake and hatchery reared fingerlings that were stocked directly into Quartz Lake. In July 2003, approximately 133,900 thermally marked rainbow trout fry from Fort Richardson fish hatchery were stocked into three fishless ponds about 14 km south of Delta Junction, Alaska. After two months of rearing about 29,400 fish were captured and stocked into Quartz Lake. In September 2003, about 76,100 unmarked rainbow trout fingerlings reared at Fort Richardson Hatchery were also stocked into Quartz Lake. In May 2004, 275 rainbow trout <200 mm were captured in Quartz Lake. We identified 186 age-1 fish of which 146 were marked (pond reared) and 40 were unmarked (hatchery reared). The relative survival rate of rearing pond fish ($p=0.78$, $SE=0.03$) was nearly twice that for fish stocked directly into Quartz Lake. This difference was not sufficient to conclude that the use of rearing ponds was a viable alternative to stocking fish directly from the hatchery. For pond rearing to be a feasible alternative, we determined that the pond reared fish must be at least two times as likely to survive to age 1. This amount of difference between the two groups of fish was necessary to offset the estimated additional costs associated with capturing and transporting the pond-reared fish to Quartz Lake. When actual operational costs were considered, the rearing pond fish needed a relative survival rate only 1.6 times that for fish stocked directly into Quartz Lake for the project to be viable.

Key words: Quartz Lake, rainbow trout, *Oncorhynchus mykiss*, relative survival rate, rearing ponds, Big Lake, West Pond, Left OP Pond, Meadows Road, age-1, fry, fingerling.

INTRODUCTION

Quartz Lake supports a major fishery in Interior Alaska generating about 7,000 angler days of fishing effort in 2003 (Jennings et al. 2006). The lake surface area is 607 ha and it is approximately 16 km north of Delta Junction (Figure 1). The Alaska Department of Fish and Game (ADF&G) stocks the lake annually with Arctic char *Salvelinus alpinus*, coho salmon *Oncorhynchus kisutch*, Chinook salmon *Oncorhynchus tshawytscha*, and rainbow trout *Oncorhynchus mykiss* (Appendix A). During 1993-2003 rainbow trout, on average, accounted for about 64% of the reported catch and harvest from Quartz Lake (Mills 1994; Howe et al. 1995, 1996, 2001a-d; Walker et al. 2003; Jennings et al. 2004, 2006, *In prep*).

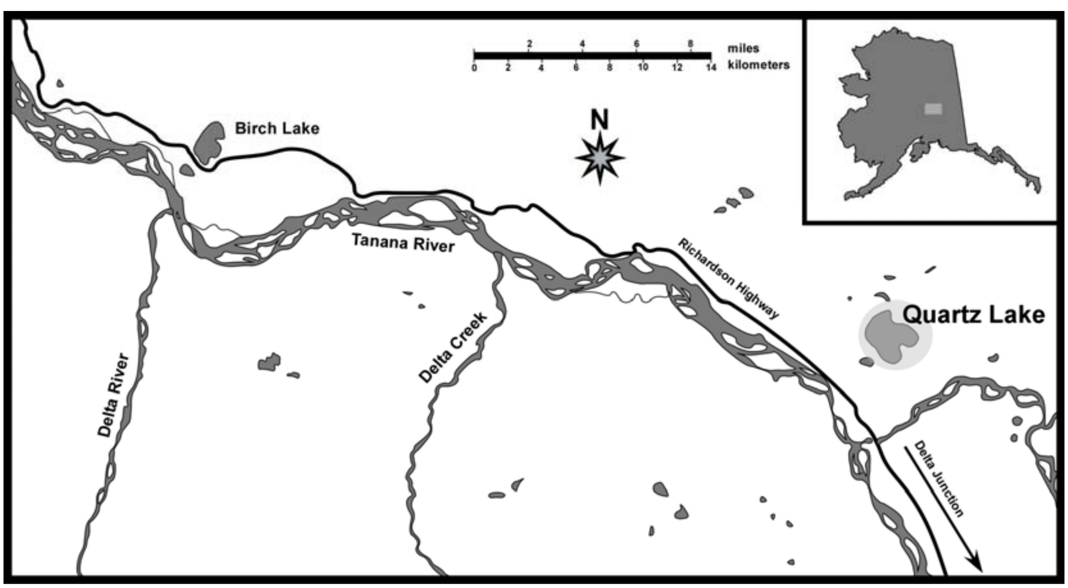

Figure 1.–Location of Quartz Lake 16 km north of Delta Junction, Alaska.

From previous studies managers had inferred that the survival rate for stocked rainbow trout to age 1 was about 5% (Skaugstad et al. 1995). However, during the late 1990s, managers began to suspect that the survival rate to age 1 had declined. A study conducted during 2001-2002 found that less than 1% of the rainbow trout fingerlings stocked directly from the hatchery into Quartz Lake survived to age 1 (Fish and Skaugstad 2004). Survival rates less than 1% would not sustain the fishery. The poor survival rate was attributed to a combination of small size at stocking, little opportunity for growth (due to stocking in late summer), and subsequent predation by larger fish.

Starting in 2002 ADF&G began stocking catchable size (100 to 120 g) rainbow trout to support the Quartz Lake fishery. The catchable rainbow trout were reallocated from other stocked lakes in the Tanana Valley that depended on annual stockings of catchable fish to sustain their fisheries. Catchable rainbow trout were reallocated from these smaller fisheries because ADF&G placed a higher priority on maintaining the fishery at Quartz Lake.

In 2003, ADF&G began investigating methods to improve the survival rate of fingerling rainbow trout into Quartz Lake. The goal was to reduce the number of catchable rainbow trout that were needed to sustain the Quartz Lake fishery. If pond reared fingerlings made a significant contribution toward sustaining the fishery then some of the catchables that were reallocated to Quartz Lake would be returned to the fisheries from where they were taken.

Because survival rates typically increase as the size at stocking increases Fish and Skaugstad (2004) proposed stocking larger fingerlings. However, due to operational constraints at the Ship Creek Hatchery complex in Anchorage, larger fingerlings could not be produced, but the hatchery could provide smaller fingerlings for earlier stockings.

Other studies by ADF&G to supplement hatchery fish production found that rearing fish in net pens was cost-effective (Clark et al. 1991; Viavant 1992). However, net-pen rearing projects have costs associated with equipment and personnel to maintain the net pens and feed the fish. A less expensive method used by Jennings (1983) was to stock fry directly into small fishless ponds. The fish grew to fingerling size unattended and were then captured in late summer and stocked out.

Our idea to improve the survival rates for rainbow trout fingerlings was to first rear rainbow trout fry in fishless ponds to fingerling size and then stock them into Quartz Lake. From previous studies we expected the fry would grow faster and be larger compared to the fingerlings that were stocked directly into Quartz Lake from the hatchery (Clark et al. 1991; Viavant 1992; and Jennings 1983).

This study was designed to compare the relative survival rates to age 1 between fingerling rainbow trout that were first reared in fishless ponds and hatchery reared fingerling rainbow trout that were stocked directly into Quartz Lake. For pond rearing to be a feasible alternative, we determined that the pond reared fish must be at least two times as likely to survive to age 1. This amount of difference between the two groups of fish was necessary to offset the estimated additional costs associated with capturing and transporting the pond-reared fish to Quartz Lake. Fishery managers will use the results from this study to design a stocking scheme that maintains a quality fishery at Quartz Lake, has minimal impact to other fisheries, and is economically acceptable.

OBJECTIVE

The objective of this study was to estimate and compare the relative survival rates to age 1 of two treatment groups of fingerling rainbow trout and to evaluate their associated costs. Treatment group 1 was stocked directly into Quartz Lake. Treatment group 2 was reared in fishless ponds prior to stocking into Quartz Lake.

METHODS

In July 2003, rainbow trout fry ($\hat{N}$=133,872[1], SE=4,535) from Fort Richardson hatchery were released into three fishless ponds on Meadows Road, near Delta Junction (Figure 2). These ponds - Left OP Pond (0.4 ha), West Pond (3.6 ha), and Big Lake (25.9 ha; Figure 2) - were first utilized as rearing ponds in the mid 1970s. All three ponds were not recently stocked, were observed to winterkill in previous years, and were believed to have no fish.

The fry were reared at Fort Richardson Hatchery and averaged 0.56 g when stocked into the ponds. Left OP Pond received 37,339 fish, West Pond received 36,594 fish, and Big Lake received 59,940 fish. All fry were "thermally-marked" at the hatchery. Three signatory marks were induced in the otoliths by manipulating water temperatures during hatchery rearing following methods described by (Hagen et al. 1995). Marks appeared as three consecutive circular bands in sectioned otoliths. After approximately two months of pond rearing, the rainbow trout were captured with fyke nets and stocked into Quartz Lake.

All fyke nets were set near shore on the lake bottom in approximately 1 to 2 m of water. The body of each fyke net was positioned parallel to shore. Fyke nets were approximately 5 m long, the open square end of each fyke net measured either 0.9 or 1.2 m on edge, trailing hoops were 0.9 m diameter, and mesh size was 9 mm^2. Leads (or "wings") were attached to both sides of the open end and measured 7.5 m long by 1.2 m deep. The wings were set to form a "V". One wing was anchored to shore, and a weight was attached to the other wing and positioned offshore. The cod end of each fyke net was pulled taunt and a weight was attached to prevent the fyke net from collapsing. Four fyke nets were used in Big Lake, two fyke nets were used in Left OP Pond and two fyke nets were used in West Pond. During high winds, 13 mm x 1.5 m pieces of conduit were driven into the lake bottom, in place of weights, to secure the nets.

The catch of each fyke net was weighed and the total number of fish was estimated using the ratio estimator described later in this section. A minimum of three samples of 100 fish from each pond was measured to the nearest mm FL to estimate the average length of fish recovered.

In September 2003, rainbow trout fingerlings ($\hat{N}$=76,081[1]; SE=879) from Fort Richardson Hatchery were stocked into Quartz Lake. Their average weight was 1.58 g and they were not marked. The average weight and stocking time for this group of fish was typical for current annual stockings of fingerling rainbow trout into Quartz Lake.

---

[1] The estimated number of fish stocked and the corresponding standard error was calculated using a ratio estimator. Detailed procedures are outlined in the *Data Analysis* section of this report.

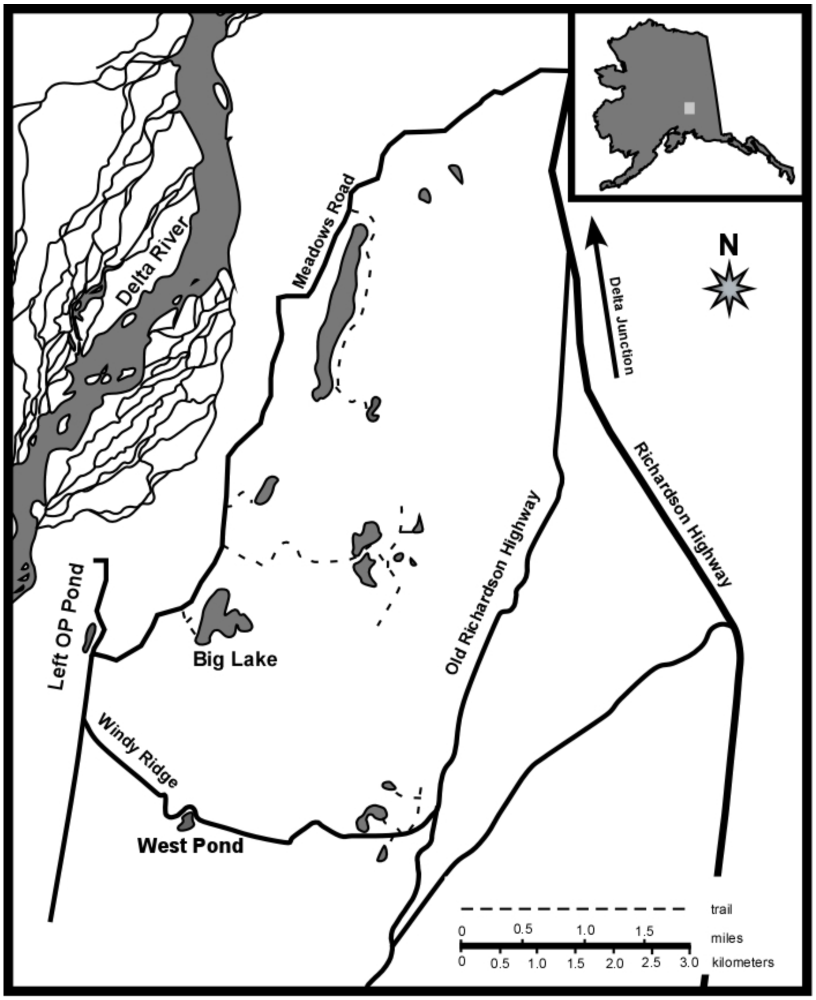

Figure 2.–Location of Left OP Pond, West Pond, and Big Lake on Meadows Road, approximately 14 km south of Delta Junction, Alaska.

In May 2004, fish were captured in Quartz Lake using fyke nets located nearshore around the lake perimeter. Nets were set in the same manner describe previously, however, four 1.2 m^2 fyke nets were equipped with center leads. A center lead was an additional net 1.75 m deep by 33 m length with float and lead lines. It was attached to the center post in the open end of a fyke net. The fyke nets with center leads were set with the center lead perpendicular to and extending to shore.

We assumed that all age-1 rainbow trout regardless of size were equally vulnerable to the sampling gear. Although fish from each treatment group may differ in average size (length or weight) prior to introduction into Quartz Lake, such differences were small and were not expected to result in any capture bias between treatment groups. This assumption was based on previous mark-recapture data from Quartz Lake where no differential vulnerability to sampling gear was detected for age-1 rainbow trout ranging in size from 55 to 170 mm (Fish and Skaugstad 2004).

Fish were captured over 5-days, May 24-28. All fish <200 mm FL were sacrificed, measured, and preserved in 95% ethanol. Previous studies at Quartz Lake showed that age-1 fish did not exceed 200 mm (Fish and Skaugstad 2004). The left sagittae otoliths were recovered in a laboratory and examined for thermal marks following procedures of Hagen et al. (1995). The presence or absence of thermally induced otolith marks determined the number of pond-reared and hatchery-reared fish recovered from Quartz Lake during 2004. The summer-to-spring relative survival rate was inferred from proportions of fish from each treatment group. The treatments were: T1 – fish stocked directly into Quartz Lake; and, T2 – fish stocked into rearing ponds and later captured and stocked into Quartz Lake. The null hypothesis:

H_o: $p_2 \leq p_o$

was tested against the alternative hypothesis:

H_a: $p_2 > p_o$

where p_2 was the proportion of age-1 rainbow trout in Quartz Lake in spring 2004 that originated in T2 and p_o was the expected proportion of fish from T2 if a fish from T2 was twice as likely to be available during spring sampling as a fish from T1. The hypothesis was evaluated using a one tailed Student's t-test (Zar 1984). The test statistic was calculated:

$$t_o = \frac{\hat{p}_2 - \hat{p}_o}{\sqrt{\hat{\text{var}}(\hat{p}_2) + \hat{\text{var}}(\hat{p}_o)}} \tag{1}$$

and if t_o was significantly (α =0.20) less than zero we rejected H_o in favor of H_a.

The degrees of freedom (df_t) for this test was calculated using the methods of Satterthwaite (1946):

$$df_t = \frac{\left[\hat{\text{var}}(\hat{p}_2) + \hat{\text{var}}(\hat{p}_o)\right]^2}{\frac{\left[\hat{\text{var}}(\hat{p}_2)\right]^2}{df_2} + \frac{\left[\hat{\text{var}}(\hat{p}_o)\right]^2}{df_o}} \tag{2}$$

where the component terms were calculated as described below. Based on simulated data and expected sample sizes, the approximate degrees of freedom was expected to exceed 120.

Because numbers of fish stocked were estimates, we used the following to estimate p_o:

$$\hat{p}_o = 2\hat{\text{N}}_{\text{T2}} / (\hat{\text{N}}_{\text{T1}} + 2\hat{\text{N}}_{\text{T2}}) \tag{3}$$

and from Mood et al. (1974):

$$\hat{\text{var}}(\hat{p}_o) = \frac{4\hat{\text{N}}_{\text{T2}}^2 \,\hat{\text{var}}(\hat{\text{N}}_{\text{T1}}) + 4\hat{\text{N}}_{\text{T1}}^2 \,\hat{\text{var}}(\hat{\text{N}}_{\text{T2}})}{(\hat{\text{N}}_{\text{T1}} + 2\hat{\text{N}}_{\text{T2}})^4} \tag{4}$$

where :

$\hat{\text{N}}_{\text{T1}}$ = the estimated total number of T1 fish stocked directly into Quartz Lake; and,

$\hat{\text{N}}_{\text{T2}}$ = the estimated total number of T2 fish stocked directly into rearing ponds.

Estimates of total numbers stocked and respective variances were calculated by multiplying the total weight of fish stocked by the estimated average number of fish per kg:

$$\hat{\text{N}}_{\text{T}k} = W_{\text{T}k}\hat{r}_{\text{T}k} \tag{5}$$

and,

$$\hat{\mathrm{var}}(\hat{\mathrm{N}}_{\mathrm{T}k}) = W_{\mathrm{T}k}^2 \; \hat{\mathrm{var}}(\hat{r}_{\mathrm{T}k}) \tag{6}$$

where $W_{\mathrm{T}k}$ was the total weight of the fish stocked in treatment Tk (k = 1, 2). The estimated number of rainbow trout per kg stocked ($\hat{r}_{\mathrm{T}k}$) was calculated using a ratio estimator (Cochran 1977):

$$\hat{r}_{\mathrm{T}k} = \sum_{i=1}^{m_{\mathrm{T}k}} c_{\mathrm{T}ki} \Bigg/ \sum_{i=1}^{m_{\mathrm{T}k}} w_{\mathrm{T}ki} \tag{7}$$

with:

$$\hat{\mathrm{var}}(\hat{r}_{\mathrm{T}k}) = m_{\mathrm{T}k} \frac{\sum_{i=1}^{m_{\mathrm{T}k}} c_{\mathrm{T}ki}^2 - 2\hat{r}_{\mathrm{T}k} \sum_{i=1}^{m_{\mathrm{T}k}} c_{\mathrm{T}ki} w_{\mathrm{T}ki} + \hat{r}_{\mathrm{T}k}^2 \sum_{i=1}^{m_{\mathrm{T}k}} w_{\mathrm{T}ki}^2}{(m_{\mathrm{T}k} - 1)\left(\sum_{i=1}^{m_{\mathrm{T}k}} w_{\mathrm{T}ki}\right)^2} \tag{8}$$

and $df_{\mathrm{T}k} = m_{\mathrm{T}k} - 1$ where,

- $m_{\mathrm{T}k}$ = the number of samples of approximately 100 rainbow trout weighed prior to stocking;
- $c_{\mathrm{T}ki}$ = the number of rainbow trout in sample i, for i = 1 to $m_{\mathrm{T}k}$; and,
- $w_{\mathrm{T}ki}$ = the total weight (kg) of the rainbow trout in sample i.

Based on historical stocking data for 2 g rainbow trout, we expected a coefficient of variation (CV) of less than 0.02 if average weight of stocked fish were estimated from a minimum of $m_k = 3$ samples of approximately 100 fish each. To ensure this level of precision, we requested that hatchery personnel obtain the weights of at least five samples from each lot of fish stocked. Additional samples were to be measured, if necessary, to achieve CV's for each treatment of less than 0.02.

We determined:

$$df_o = \min(df_{num}, df_{den}) \tag{9}$$

where df_{num} (see equation 2) was the degrees of freedom for the estimated value $2\hat{\mathrm{N}}_{\mathrm{T}1}$ ($df_{num} = df_{\mathrm{T}2}$) and df_{den} was the degrees of freedom for the estimated value $\hat{\mathrm{N}}_{\mathrm{T}1} + 2\hat{\mathrm{N}}_{\mathrm{T}2}$ which was calculated using the methods of Satterthwaite (1946):

$$df_{den} = \frac{\left[\hat{\mathrm{var}}(\hat{\mathrm{N}}_{\mathrm{T}1}) + 4\,\hat{\mathrm{var}}(\hat{\mathrm{N}}_{\mathrm{T}2})\right]^2}{\frac{\left[\hat{\mathrm{var}}(\hat{\mathrm{N}}_{\mathrm{T}1})\right]^2}{df_{\mathrm{T}1}} + \frac{\left[4\,\hat{\mathrm{var}}(\hat{\mathrm{N}}_{\mathrm{T}2})\right]^2}{df_{\mathrm{T}2}}} \tag{10}$$

Following inspection of otoliths of fish collected during sampling in spring 2004 we estimated:

$$\hat{p}_2 = \frac{n_2}{n} \text{, and,} \tag{11}$$

$$\hat{\mathrm{var}}(\hat{p}_2) = \frac{\hat{p}_2(1-\hat{p}_2)}{n-1} \tag{12}$$

where,

n_2 = the total number of T2 fish in the spring sample,

n = the total number of sub-catchable (T1 plus T2) fish in the spring sample, and,

df_2 = n - 1.

The actual required sample size to test the difference between two parameter estimates was calculated prior to spring sampling by using the proper substitutions and solving for *n* in:

$$t_\alpha + t_\beta = CD / \sqrt{\hat{\mathrm{var}}(\hat{p}_o) + \hat{\mathrm{var}}(\hat{p}_2)} \tag{13}$$

where *CD* represents the difference between 2:1 and 2.5:1 in probability of recovery of T2 fish over that of T1 fish and the *t*-values were the appropriate critical values from tables of Student's *t* distribution.

If H_o was rejected in favor of H_a, pond rearing was considered a successful alternative to hatchery production and a management action that should be continued until hatcheries can produce larger rainbow trout fingerlings for lake stocking.

RESULTS

In September 2003, an estimated 29,352 (SE=1,695) rainbow trout fry were recovered from the rearing ponds and stocked into Quartz Lake. The overall recovery rate was about 22%. Two technicians spent nearly two weeks checking nets and transporting fish each day. We calculated that it cost about $4,000 to capture the fish and stock them into Quartz Lake.

Fish recovered from Big Lake, West Pond, and Left OP Pond had average fork lengths of 84 mm, 57 mm, and 54 mm respectively. Fish reared in Big Lake grew an average of 5 g, while fish reared in West Pond and Left OP Pond grew approximately 1 g (Table 1).

Table 1.–Rainbow trout fed-fry stocked into rearing ponds, percent recovered, and average growth, July-September 2004.

	Big Lake	**West Pond**	**Left OP Pond**
Fish Stocked (July 2004)[a]	59,940	36,594	37,339
Average Weight (g) at stocking	0.56	0.56	0.56
Fish Recovered (September 2004)[b]	15,081	821	13,451
% Recovery	25%	2%	36%
Average Fork Length (mm) at Recovery	84	57	54
Average Weight (g) at Recovery	5.56	1.76	1.54
Average Weight Gain (g)	5.00	1.20	0.98

[a] SE=4,535 for all fish stocked into rearing ponds.

[b] SE=1,695 for all fish recovered form rearing ponds.

In May 2004, 275 rainbow trout <200 mm were captured in Quartz Lake. The length frequency distribution indicated that the size range was adequate to encompass all age-1 fish caught during the sampling event (Figure 3). Left sagittae otoliths were extracted and examined for annuli and thermal marks. We identified 186 age-1 fish of which 146 were marked and 40 were unmarked. The remaining fish were older than age 1 or the otoliths were damaged during processing and could not be read. Older fish were identified by the presence of additional annuli.

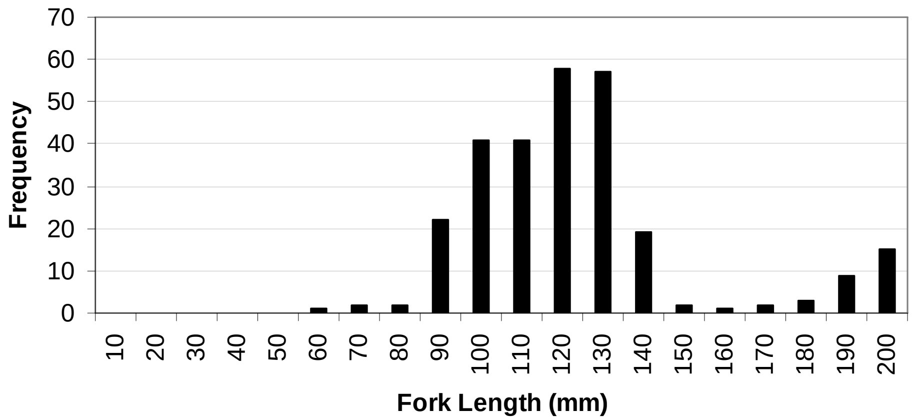

Figure 3.–Length frequency distribution of Quartz Lake rainbow trout < 200 mm, May 2004.

The proportion of age-1 rainbow trout in Quartz Lake in spring 2004 that originated from rearing ponds was 0.78 (SE=0.030). The expected proportion of fish originating from the rearing ponds was 0.78, (SE=0.006). Results from the Student's t-test indicated that there was no significant difference between these two proportions (to=0.20189, df=201); however, sampling intensity was not sufficient to achieve the design criteria for this test (80% power of detecting a difference of 2.5 times with $\alpha = 0.20$).

DISCUSSION

When planning this project we inferred from previous observations and personal experience that rainbow trout fry raised in fishless ponds would grow 4 g or more in size and that at least 20% of fish would be recovered from each pond. Results from Big Lake exceeded expectations. The lack of predation and the presence of forage species may have contributed to this success.

Conversely, Left OP and West Ponds did not produce anticipated results. Left OP Pond, once approximately 3.2 ha surface area, was less than 0.4 ha at the time fish were stocked and the maximum depth was less than 1 m. This drastic reduction in lake size diminished the habitat available to juvenile fish and forage species. Previously submerged vegetation was exposed and few invertebrates, larvae, and other forage were observed. The small lake size and reduced habitat and food resources may explain the limited growth (0.98 g) and the relatively high recovery rate (36%).

West Pond was approximately 2.4 m deep and was thought to winterkill each year; however, we discovered that age-1 rainbow trout were also present in the lake. These fish were remnants from another rearing pond project conducted in 2002. The low recovery rate (2%) may have been the result of predation by the age-1 fish.

The design criteria for this study were not met in part because the average weight of fry stocked into rearing ponds was estimated using the weights of only four groups of approximately 100 to 200 fish, not the specified five groups. The resulting CV (0.034) was larger than what was desired (< 0.02). Another reason that the design criteria were not met was because we underestimated the number of fish that were needed to obtain an adequate sample size of readable otoliths. From both cases, inadequate sample sizes decreased the power of the one tailed Student's *t*-test.

Based on the original assumptions and design criteria for this study we concluded that rearing fish in ponds before stocking them into Quartz Lake was not a viable alternative. However, when we considered the actual recovery rates of fish from the rearing ponds and the actual operational costs to recover and stock them into Quartz Lake, the project would be viable when the relative survival rate to age 1 for pond reared fish was ≥ 1.6 times that for fish stocked directly into Quartz Lake. Using this criteria, we would expect the pond reared fish to comprise at least 0.74 (SE=0.007) of the population of age-1 fish in Quartz Lake. When we compared this proportion to that observed during this study (0.78, SE=0.030) the difference was significant (t_o=1.51806, df=205). Consequently, rearing ponds were a cost effective alternative to stocking fish directly into Quartz Lake.

This study provided information necessary to more accurately evaluate costs, fish growth and recovery rates associated with rearing pond activities and allowed researchers to identify how future pond rearing projects can be modified to further lower costs and increase fish growth. Increasing the number of days between checking the nets to two or even three days as catches decline would reduce the amount of labor required to recover and transport fish. Operations also will become more stream-lined as personnel gain experience and become more efficient with capture gear, handling, and transporting fish. Finding and using other ponds that have fish growth rates comparable to that for Big Lake would likely increase the survival rate to age 1 for fingerlings stocked into Quartz Lake.

The insights and experience acquired from this study can be used to improve future pond-rearing activities. With the survival rates observed in this study and the additional analysis conducted with new cost and recovery data, we believe that pond rearing is a feasible method to improve the quality of the Quartz Lake fishery. To better achieve this goal we recommend the following actions:

1) Continue pond-rearing activities at Big Lake;
2) Eliminate the use of Left OP Pond and West Pond in future projects;
3) Investigate other potential rearing ponds with morphological characteristics similar to Big Lake; and,
4) During capture operations, check the nets daily for the first week, but less frequently thereafter.

ACKNOWLEDGEMENTS

Jim Fish assisted with project planning and logistical support. Dan Reed provided biometric review. Kelly Mansfield, Justin Crawford, Kimberly Stephens, Melissa McInelly, Holly Carroll, and Shannon Spring assisted with field work. Sara Case provided editorial and formatting assistance. The U.S. Fish and Wildlife Service provided partial funding for this study through the Federal Aid in Sport Fish Restoration Act (16 U.S.C. 777-777K) under Project F-10-19, Job No. E-3-1.

REFERENCES CITED

Clark, J. H., T. R. Viavant, C. Skaugstad, and T. R. McKinley. 1991. Growth, survival, and costs of rearing game fish in floating net-pens at Harding Lake, Alaska, 1990. Alaska Department of Fish and Game, Fishery Data Series No. 91-2, Anchorage.

Cochran, W. G. 1977. Sampling techniques, third edition. John Wiley and Sons, New York.

Fish, J. T. and C. Skaugstad. 2004. Evaluation of rainbow trout in Quartz Lake, 2001 and 2002. Alaska Department of Fish and Game, Fishery Data Series No. 04-02, Anchorage.

Hagen, P., K. Munk, B. Van Alem, and B. White. 1995. Thermal mark technology for inseason fisheries management: a case study. Alaska Fishery Research Bulletin 2(2):143-155.

Howe, A. L., G. Fidler, and M. J. Mills. 1995. Harvest, catch, and participation in Alaska sport fisheries during 1994. Alaska Department of Fish and Game, Fishery Data Series No. 95-24, Anchorage.

Howe, A. L., G. Fidler, A. E. Bingham, and M. J. Mills. 1996. Harvest, catch, and participation in Alaska sport fisheries during 1995. Alaska Department of Fish and Game, Fishery Data Series No. 96-32, Anchorage.

Howe, A. L., R. J. Walker, C. Olnes, K. Sundet, and A. E. Bingham. 2001a. Revised Edition. Harvest, catch, and participation in Alaska sport fisheries during 1996. Alaska Department of Fish and Game, Fishery Data Series No. 97-29 (revised), Anchorage.

Howe, A. L., R. J. Walker, C. Olnes, K. Sundet, and A. E. Bingham. 2001b. Revised Edition. Harvest, catch, and participation in Alaska sport fisheries during 1997. Alaska Department of Fish and Game, Fishery Data Series No. 98-25 (revised), Anchorage.

Howe, A. L., R. J. Walker, C. Olnes, K. Sundet, and A. E. Bingham. 2001c. Revised Edition. Participation, catch, and harvest in Alaska sport fisheries during 1998. Alaska Department of Fish and Game, Fishery Data Series No. 99-41 (revised), Anchorage.

Howe, A. L., R. J. Walker, C. Olnes, K. Sundet, and A. E. Bingham. 2001d. Participation, catch, and harvest in Alaska sport fisheries during 1999. Alaska Department of Fish and Game, Fishery Data Series No. 01-8, Anchorage.

Jennings, G. B., K. Sundet, A. E. Bingham, and D. Sigurdsson. 2004. Participation, catch, and harvest in Alaska sport fisheries during 2001. Alaska Department of Fish and Game, Fishery Data Series No. 04-11, Anchorage.

Jennings, G. B., K. Sundet, A. E. Bingham, and D. Sigurdsson. 2006. Participation, catch, and harvest in Alaska sport fisheries during 2002. Alaska Department of Fish and Game, Fishery Data Series No. 06-34, Anchorage.

Jennings, G. B., K. Sundet, A. E. Bingham, and D. Sigurdsson. *In prep*. Participation, catch, and harvest in Alaska sport fisheries during 2003. Alaska Department of Fish and Game, Fishery Data Series, Anchorage.

Jennings, T. R. 1983. Survival, growth and food habits of age-0 Arctic grayling stocked in barren, sub-Arctic lakes. Master of Science Thesis, University of Alaska, Fairbanks, Alaska.

Mills, M. J. 1994. Harvest, catch, and participation in Alaska sport fisheries during 1993. Alaska Department of Fish and Game, Fishery Data Series No. 94-28, Anchorage.

Mood, A. M., F. A. Graybill, and D. C. Boes. 1974. Introduction to theory of statistics, third edition. McGraw-Hill, New York.

REFERENCES CITED (Continued)

Satterthwaite, F. E. 1946. An approximate distribution of estimates of variance components. Biometrics 2:110-114.

Skaugstad, C., P. Hansen, and M. Doxey. 1995. Evaluation of stocked game fish in the Tanana Valley, 1994. Alaska Deptartment of Fish and Game, Fishery Data Series No. 95-20, Anchorage.

Viavant, T. R. 1992. Growth, survival, and costs of rearing rainbow trout in floating net-pens at Harding Lake, Alaska, 1991. Alaska Department of Fish and Game, Fishery Data Series No. 92-1, Anchorage.

Walker, R. J., C. Olnes, K. Sundet, A. L. Howe, and A. E. Bingham. 2003. Participation, catch, and harvest in Alaska sport fisheries during 2000. Alaska Department of Fish and Game, Fishery Data Series No. 03-05, Anchorage.

Zar, J. H. 1984. Biostatistical Analysis, second edition. Prentice-Hall Inc. Englewood Cliffs, New Jersey.

APPENDIX A
STOCKING HISTORY FOR QUARTZ LAKE, 2000-2004

Appendix A.–Stocking history for Quartz Lake, 2000-2004.

Species	Date	Number	Average FL (in)	Average FL (mm)
Coho Salmon	12-Jun-00	84,321	2.9	74
Coho Salmon	3-Aug-00	14,978	3.7	94
Rainbow Trout	3-Aug-00	66,369	1.8	46
Rainbow Trout	3-Aug-00	286,362	2.1	53
Chinook Salmon	22-Sep-00	10,000	7.6	193
Coho Salmon	11-Jun-01	58,000	2.6	66
Rainbow Trout	11-Jun-01	85	12.3	312
Rainbow Trout	11-Jun-01	2,507	8.6	218
Rainbow Trout	11-Jun-01	2,500	8.8	224
Rainbow Trout	28-Jun-01	2,745	8.5	216
Rainbow Trout	5-Jul-01	2,705	8.5	216
Rainbow Trout	5-Jul-01	6,982	8.5	216
Rainbow Trout	8-Aug-01	78,705	1.8	46
Rainbow Trout	8-Aug-01	146,884	1.8	46
Rainbow Trout	8-Aug-01	46,772	1.9	48
Arctic Char	31-Aug-01	9,065	4.2	107
Rainbow Trout	31-Aug-01	27,775	2.5	64
Rainbow Trout	31-Aug-01	13,108	2.5	64
Rainbow Trout	3-Jun-02	6,682	8	203
Rainbow Trout	13-Jun-02	2,883	7.8	198
Rainbow Trout	27-Jun-02	7,005	9.7	246
Rainbow Trout	14-Aug-02	85,726	1.9	48
Rainbow Trout	14-Aug-02	167,767	2	51
Rainbow Trout	14-Aug-02	75,674	1.9	48
Rainbow Trout [a]	1-Sep-02	11,983	-	-
Arctic Char	4-Sep-02	6,285	3.6	91
Rainbow Trout	27-May-03	13,294	8	203
Coho Salmon	3-Jun-03	61,826	2.6	66
Rainbow Trout	25-Jun-03	1,590	8.3	211
Rainbow Trout	9-Jul-03	2,952	8.3	211
Rainbow Trout	9-Jul-03	2,755	9.6	244
Rainbow Trout	20-Aug-03	76,712	2.1	53
Rainbow Trout [a]	1-Sep-03	29,352	2.6	65
Coho Salmon	14-May-04	30,407	2.3	58
Rainbow Trout	14-May-04	6,291	8.9	226
Coho Salmon	28-May-04	2,782	2.2	56
Rainbow Trout	4-Jun-04	9,519	8.7	221
Rainbow Trout	22-Jun-04	2,000	9	229
Rainbow Trout	19-Jul-04	51,746	1.9	48
Rainbow Trout	17-Aug-04	60,071	2	51
Arctic Char	19-Aug-04	9,504	2.6	66
Rainbow Trout	26-Aug-04	75,196	2.2	56
Rainbow Trout	26-Aug-04	49,397	2.3	58
Chinook Salmon	22-Sep-04	5,000	8.1	206
Rainbow Trout [a]	1-Sep-04	34,829	2.6	67
Rainbow Trout [b]	30-Sep-04	438	10+	250+
Rainbow Trout	3-Nov-04	318	7.9	201
Rainbow Trout	3-Nov-04	11,000	2.6	66

[a] Fish transferred from rearing ponds.
[b] Fish transferred form Lost Lake to Quartz Lake.

APPENDIX B

ARCHIVE FILES FOR DATA COLLECTED DURING STUDIES COVERED IN THIS REPORT

Appendix B.–Archive files for data collected during studies covered in this report.

File Name [a]	Description
RT age-1 Survival Quartz May 27,2004.xls	Excel spreadsheet file that includes all the length, weight, stocking and capture information from the experiment.
Quartz Lake Data Analysis.xls	Excel spreadsheet file that contains all the data analysis performed for this report
Quartz Lake Age-1 Otolith Data.xls	Excel spreadsheet file that contains all the data from the otoliths collected from rainbow trout in Quartz Lake in 2004.

[a] Data files are available from the Alaska Department of Fish and Game, Division of Sport Fish, 1300 College Rd, Fairbanks, Alaska 99701.